I. GEOLOGY, SOILS, AND SEISMICITY

This section assesses the geotechnical conditions potentially affecting the North Park Street Code area. Potential impacts from strong ground shaking, liquefaction, and differential settlement that could result from seismic activity are also assessed in this section. The analysis is based on the review of a published report on geologic, hydrogeologic, and seismic conditions within the eastern portion of the San Francisco Bay region and geotechnical investigations previously prepared for projects within the boundaries of the North Park Street Code area. The sources of regional information include the U.S. Geological Survey, U.S. Soil Conservation Service, California Department of Water Resources, California Geological Survey (formerly the California Division of Mines and Geology), San Francisco Bay Regional Water Quality Control Board, and the Alameda Flood Control and Water Conservation District.

1. SETTING

The North Park Street Code area is located at the western coastal margin of the Coast Range Geomorphic Province in the San Francisco Bay region. This region is dominated by northwest-southeast trending ridges and valleys with the structure of the region controlled by the tectonic activity within the San Andreas fault system. The San Andreas fault system, which includes the San Andreas fault, Hayward fault and other faults in the San Francisco Bay Area, is an area of active seismicity which is located at the boundary between two major tectonic plates, the North American and Pacific Plates.

The North Park Street Code area is located on the eastern margin of San Francisco Bay. More specifically, the area occupies the northern portion of Alameda Island. The Island is bounded to the west and south by San Francisco Bay, and to the north by Oakland Harbor (a dredged shipping channel). Prior to development, which began in the 1800s, the environmental setting of this area of the margin of the Bay was estuarine with substantial beaches and dunes formed along the margin of the Oakland Estuary. The Estuary, later developed as the Oakland Harbor, separated Alameda from the Oakland waterfront. The Oakland Estuary formed the lower reach of San Antonio Creek. Historically, the harbor was significantly wider until filling on both sides of the harbor resulted in the relatively narrow, modern shipping channel.

a. Topography

The entire North Park Street Code area occupies a relatively flat filled area adjacent to the Inner Harbor Tidal Channel. There are no natural slopes greater than a few feet in height.

b. Geology and Soils

The surficial geology of the North Park Street Code area and the surrounding area reflects the late Quaternary geologic history and the placement of large volumes of artificial fill. The main process which controlled the geologic history of the area was the formation of San Francisco Bay and periodic fluctuations in global and local sea level. San Francisco Bay occupies a down-warped basin between the Hayward and Calaveras fault zones on the east and the San Andreas fault zone to the west.

The near-surface geology in Alameda is dominated by three general geotechnical units: Merritt Formation sands (also known as Merritt Sand), younger Bay Mud, and artificial fill. Prior to the placement of artificial fill, the Merritt Formation sands were exposed as dry land on the central and southern portions of the present Alameda Island, as well as along the Oakland waterfront. The Merritt Formation is generally characterized as dense, well-sorted (poorly graded), fine- to medium-grained quartz sand deposits ranging in thickness from 0 to 80 feet. The sands contain relatively thin layers of silts, silty clays, and clays. The Merritt Formation is underlain by older Bay Mud, which was deposited during a previous period of high sea level, and older Quaternary alluvial deposits of the San Antonio and Alameda Formations.

Younger Bay Mud was deposited on top of a sloping surface of the exposed Merritt Sand. The younger Bay Mud was deposited during the most recent period of global sea level rise, which marks the Holocene epoch (the last 11,000 years). A complex system of tidal channels formed within the marsh. The channels were inundated by daily tides; the whole marsh surface would be inundated during seasonal high tides, and possibly by storm waves. The tidal channel system was a dynamic environment, and the channel locations shifted over time. The younger Bay Mud is predominantly composed of clayey silt, silty clay and clay with discontinuous sand and occasional gravel layers or lenses, which represent tidal channel deposits.

c. Seismic Conditions

The North Park Street Code is located in the San Francisco Bay Region of Northern California, a tectonically active region. Active seismicity within the region is primarily a result of active fault movement within the San Andreas Fault System (SAFS), a complex of active faults that includes the San Andreas, Hayward, Calaveras, Rogers Creek and other faults in the area. Earthquakes commonly occur due to movement along faults and fractures within the earths crust. Numerous moderate to strong historic earthquakes have been generated in Northern California.

The San Francisco Bay Region, including the North Park Street Code area, is classified as Seismic Risk Zone 4 in the Uniform Building Code (1997) due to the level of seismic activity.[1]

The fault system includes numerous active faults, faults found by the California Geological Survey under the Alquist-Priolo Earthquake Fault Zone Act (1972) to have evidence of fault rupture within the last 11,000 years. The Working Group on California Earthquake Probabilities has estimated that there is an aggregate 70 percent probability of one or more large earthquakes (Magnitude 6.7 or greater) occurring in the San Francisco Bay Area by 2030.

1 Zone 4 of the UBC identifies areas within the United States, including California, which have the highest seismic risk and require more stringent seismic design criteria. The entire San Francisco Bay region is designated UBC Zone 4.

d. Surface Fault Rupture

Surface fault rupture occurs when the ground surface is broken due to fault movement during an earthquake. Surface fault rupture generally occurs along an active or potentially active major fault trace, although there have been some cases where supposedly inactive faults have experienced displacement during earthquakes centered on nearby faults.[2] No active faults have been mapped at the North Park Street Code area; therefore, the potential for surface fault rupture at the site is considered very low. The site is not located within an Alquist-Priolo Earthquake Fault Zone boundary.

The closest active fault to the North Park Street Code area is the Hayward fault, located approximately 4 miles to the northeast. The Hayward fault generated a large magnitude (approximate magnitude 7) earthquake in 1868. Other smaller earthquakes occur on the Hayward fault on an on-going basis and it is an active seismic source. Although the East Bay was relatively undeveloped at the time, substantial structural damage occurred during the 1868 earthquake and during the 1906 Great San Francisco Earthquake. Two distinct segments of the Hayward fault are generally recognized as capable of generating large magnitude earthquakes. The northern segment extends from San Pablo Bay to San Leandro. The 1868 earthquake was generated on the southern segment, which extends from San Leandro to east San Jose.

e. Seismic-Induced Ground Shaking

Seismic-induced ground shaking refers to motion of the earth's surface resulting from an earthquake, and is normally the major cause of damage during seismic events. The level of seismic-induced ground shaking is controlled by the magnitude and intensity of the earthquake, distance from the epicenter, depth of the earthquake, and local geologic conditions.

Magnitude is a measure of the energy released by an earthquake; it is assessed by seismographs, which measure the amplitude of seismic waves. The Richter magnitude scale is the most commonly used measure of the strength of an earthquake. Intensity is a measure of the effects of seismically induced ground shaking at a given location and varies with distance from the epicenter, local geologic conditions, and intervening faults and structure. The Modified Mercalli Intensity Scale (MMI) is the most commonly used scale for measurement of the effects of earthquake intensity. Intensity can also be quantitatively measured using accelerometers (strong motion seismographs), which record ground acceleration at a specific location, a measure of force applied to a structure under seismic shaking. Acceleration is measured as a fraction or percentage of the acceleration under gravity (g).

Estimates of the peak ground acceleration have been made for the area based on probabilistic models that account for multiple seismic sources. Under these models, consideration of the probability of expected seismic events is incorporated into the determination of the level of ground shaking at a particular location. The expected peak ground acceleration (with a 10 percent chance of

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[2] Op cit. D.J. Rodgers and S.H. Figuers, 1991.

being exceeded in the next 50 years) generated at the North Park Street Code area by any of the seismic sources potentially affecting the area is estimated by the California Geological Survey to be 0.5 to 0.6g. This level of ground shaking in the North Park Street Code area is a potentially serious hazard.

The San Andreas fault is located 13 miles west of the North Park Street Code area, where it transects the San Francisco Peninsula. The San Andreas fault in northern California has been divided into distinct segments. The 1906 San Francisco earthquake (estimated magnitude 7.9) was generated when the North Coast segment of the San Andreas fault ruptured from San Juan Bautista in San Benito County to Shelter Cove in Humboldt County. This event caused extensive damage throughout the San Francisco Bay region, particularly in areas underlain by filled lands and young alluvial and Bay sediments. An earthquake of this magnitude could produce Modified Mercalli Intensity of IX at the North Park Street Code area (http://quake.abag.ca.gov), the intensity of groundshaking experienced during the 1906 earthquake.

The 1989 Loma Prieta earthquake (magnitude 6.9) was generated by rupture of another segment of the San Andreas fault, the South Santa Cruz Mountains segment. This was the first large magnitude earthquake to affect the San Francisco Bay region since 1906 and resulted in major regional as well as local damage. Especially prone to damage were areas filled with hydro-compacted sand and areas underlain by saturated low-density sand deposits. The recorded ground motion in downtown Oakland and on Alameda Island was significantly higher than would be predicted by standard empirical relationships relating attenuation of seismic shaking to distance from the fault causing the earthquake. Horizontal ground acceleration measured at two locations ranged from 0.21 to 0.29g. The amplification of ground motion was apparently related to the thickness and characteristics of unconsolidated Pleistocene and younger sediments, and the configuration of the underlying bedrock surface.[3] Shaking intensity for this earthquake was VII for the North Park Street Code on the Modified Mercalli Intensity scale (http://quake.abag.ca.gov).

f. <u>Liquefaction</u>

Liquefaction is the temporary transformation of loose, saturated granular sediments from a solid state to a liquefied state as a result of seismic ground shaking. In the process, the soil loses strength, which commonly allows ground displacement or ground failure (including lurching and lateral spreading) to occur. Because saturated soils are a necessary condition for liquefaction, soil layers in areas where the groundwater table is near the surface have higher liquefaction potential than those in which the water table is deep. Shallow groundwater occurs within the North Park Street Code area at depths ranging from 2 to 8 feet below the ground surface (bgs) in fill materials and Bay Mud.

The Association of Bay Area Governments web site (http://abag.ca.gov) includes maps of liquefaction potential. The North Park Street Code area is mapped as having a very high potential for liquefaction.

Table IV.I-1: Modified Mercalli Scale[a]

[3] Op. Cit. D.J. Rodgers and S. H. Figuers, 1991.

	Intensity	**Effects**	**v,[b] cm/s**	**g[c]**
M[d]	I.	Not felt. Marginal and long-period effects of large earthquakes.		
3	II.	Felt by persons at rest on upper floors or favorably placed.		
	III.	Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.		0.0035-0.007
4	IV.	Hanging objects swing. Vibration like passing of heavy trucks, or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frame creak.		0.007-0.015
	V.	Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.	1-3	0.015-0.035
5	VI.	Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle - CFR).	3-7	0.035-0.07
6	VII.	Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments - CFR). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.	7-20	0.07-0.15
	VIII.	Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.	20-60	0.15-0.35
7	IX.	General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations - CFR.) Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake foundations, sand craters.	60-200	0.35-0.7
8	X.	Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.	200-500	0.7-1.2
	XI.	Rails bent greatly. Underground pipelines completely out of service.		>1.2
	XII.	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.		

[a] From Richter (1958).
[b] Average peak ground velocity, cubic meters per second.
[c] Average peak acceleration (away from source).
[d] Richter magnitude correlation.

Notes:
- *Masonry A, B, C, D.* To avoid ambiguity of language, the quality of masonry, brick or otherwise, is specified by the following lettering (which has no connection with the conventional Class A, B, C construction).
- *Masonry A:* A Good workmanship, mortar, and design, reinforced, especially laterally, and bound together by using steel, concrete, etc; designed to resist lateral forces.
- *Masonry B:* Good workmanship and mortar, reinforced, but not designed to resist lateral forces.
- *Masonry C:* Ordinary workmanship and mortar; no extreme weaknesses such as non-tied-in corners, but masonry is neither reinforced nor designed against horizontal forces.
- *Masonry D:* Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

Loose, saturated sands and silty sands in fill underlie some portions of the North Park Street Code area. These soils may have a high susceptibility to liquefaction. Other areas of the North Park Street Code area contain soils susceptible to liquefaction as well. Sandy or silty deposits within the younger

Bay Mud may also be subject to liquefaction. Liquefaction of these sediments would be expected during large magnitude earthquakes on the Hayward fault and San Andreas fault, and possibly during large earthquakes on other regional fault zones. In general, the Merritt Formation is sufficiently dense that liquefaction is not expected to occur.

g. Slope Stability

The North Park Street Code area is located on relatively flat topography at the margin of the Oakland Estuary. There are no steep slopes that may be subject to slope failure, with the exception of slopes adjacent to the estuary.

h. Settlement

The younger Bay Mud underlying the site are poorly consolidated and, upon loading, would undergo consolidation that would lead to substantial settlement. The consolidation process and associated settlement occur at a relatively slow rate, but can result in significant damage to foundations and structures that have not been properly designed and constructed.

Total settlement is measured as the sum of two main components: primary consolidation settlement (primary settlement) and secondary compression. Primary settlement occurs because of additional loading imposed on a compressible soil layer. Secondary compression, caused by realignment of clay minerals and by compression of organic rich soil, is known to occur in Bay Mud and peaty soils, both of which were observed in boreholes drilled within the North Park Street Code area.

The amount of primary settlement that occurs at a given location is a function of the thickness of the Bay Mud, the weight of additional fill and/or structures, and time. Geotechnical investigations conducted at sites within North Park Street Code area and vicinity have evaluated historic settlement in these areas and the potential for further consolidation and settlement.,[4]

The amount of secondary compression will vary across the site depending on the thickness of compressible materials. It is estimated that secondary compression will total between 0.5 and 1.5 inches for building pads constructed over compressible deposits.[5] Secondary compression will occur gradually over the next several hundred years.

2. IMPACTS AND MITIGATION MEASURES

Geologic hazards that may affect the North Park Street Code area during the construction and post-construction periods include ground shaking, liquefaction, and associated ground failure. In addition, continued settlement in response to consolidation of subsurface materials may damage improvements. This section begins with a description of the criteria used to determine whether any significant geology, soils and seismicity impacts would result. The less-than-significant, potentially significant and significant impacts of the North Park Street Code are discussed below.

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[4] Op. Cit. URS Greiner Woodward Clyde, 1999.

[5] Op. Cit. URS Greiner Woodward Clyde, 1999.

a. Significance Criteria

A potentially significant impact would result if the North Park Street Code area would result in or expose people or structures to any of the following:

- Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault;
- Strong seismic ground shaking;
- Seismic-related ground failure, including liquefaction;
- Landslides;
- Substantial soil erosion or the loss of topsoil;
- Soil that is unstable or that would become unstable as a result of the project, and potentially result in on-site or off-site landslide, lateral spreading, subsidence, structural failure of public facilities, or liquefaction; or
- Expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1997), creating substantial risks to life or property.

For the purpose of this EIR, significant geologic hazards would pertain to soil and/or seismic conditions so unfavorable that they could not be overcome by reasonable design, construction, and maintenance practice; in addition, exposing an increased number of people to risk of injury would constitute a significant impact.

b. Less-than-Significant Impacts

The potential for surface fault rupture at the site is very low, because no active faults are known to be located in the North Park Street Code area; the closest active fault, the Hayward fault, is located approximately 4 miles to the northeast. The potential for significant slope instability at the site is limited due to the absence of steep, high slopes, with the exception of the marina and channel bulkheads. The relatively flat topography of the site also limits the potential for high runoff rates and significant erosion. The near-surface soils at the site (predominantly sandy fill deposits) have a low potential for shrink-swell, limiting the adverse effects of expansive soils to a less-than-significant level.

c. Significant Impacts

Development under the North Park Street Code could result in potentially significant impacts related to exposure to seismic hazards (including liquefaction and associated lateral spreading) and ground surface settlement, as discussed below.

Impact GEO-1: Occupants of future development within the North Park Street Code area would be subject to seismic-induced ground shaking.

All structures in the Bay Area could potentially be affected by seismic induced ground shaking in the event of an earthquake. The level of ground shaking depends on the magnitude of the earthquake, the distance from the epicenter, and the type of earth materials in between. Very strong to violent ground shaking is expected in the North Park Street Code area during expected earthquakes on the Hayward, Calaveras, and San Andreas faults. This level of seismic shaking could cause extensive non-structural and structural damage to buildings at the site. The following mitigation measure shall be implemented in order to reduce this impact to a less-than-significant level.

> **<u>Mitigation Measure GEO-1</u>:** Grading, foundation, and structural design should be based on the anticipated strong seismic shaking associated with a future major earthquake on the Hayward fault. The Hayward fault is considered to be a Type A seismic source (with active slip and capable of a magnitude 7.0 or greater earthquake) under the 1997 Uniform Building Code (UBC) near-source factors. All structures shall be designed in accordance with the most recent edition of the City of Alameda Building Code.
>
> The applicant shall prepare an earthquake preparedness and emergency response plan for all public use facilities. The plan should be submitted for review and approval by the Planning and Building and/or Public Works Department, prior to occupancy of the structures.
>
> Prior to marketing residential or commercial units for sale, the developer shall prepare an earthquake hazards information document. This document should be made available to any potential occupant prior to purchase or rental of the housing units or commercial spaces. The document should describe the potential for strong ground shaking at the site, potential effects of such shaking, and earthquake preparedness procedures.

Implementation of these measures would reduce the impact of seismic-induced ground shaking to less than significant levels.

Impact GEO-2: Seismic-induced Ground Failure, including Liquefaction, Lurch-Cracking and Lateral Spreading may occur in the North Park Street Code area.

Sediments underlying the North Park Street Code area have a high liquefaction potential. Damage related to liquefaction including settlement, lurch cracking, or lateral spreading could occur. Settlement or ground failures due to movements within the bulkhead during a seismic event could cause considerable damage to structures that may be placed near the top of the bulkhead slope.

> **<u>Mitigation Measure GEO-2:</u>** Earthwork, foundation and structural design for proposed projects shall be conducted in accordance with all recommendations contained in a Geotechnical Investigation to be completed for each development site. Liquefaction potential analyses shall be conducted and a liquefaction mitigation program developed for each development within the North Park Street Code area. All structures proposed within the North Park Street Code area shall be designed and constructed in accordance with the

most recently adopted version of the City of Alameda Building Code. Prior to the issuance of any grading or building permits for new buildings, geotechnical investigations shall be conducted for projects within the North Park Street Code area. Reports for these studies shall evaluate the liquefaction potential for each site in accordance with the Standard of Practice for Geotechnical Engineering and shall provide recommendations for stabilization or resistance of structures from the potential affect of liquefaction of sediments. The potential for lurch cracking and lateral spreading shall also be evaluated. Stability of the bulkhead for projects adjacent to bulkheads shall also be evaluated. Reports shall be submitted to the City of Alameda for review and approval.

Implementation of these mitigation measures would reduce the impact of seismic-induced ground failure to less than significant levels.

Impact GEO-3: Expected continuing consolidation and land subsidence in the North Park Street Code area could result in damage to structures, utilities and pavements.

Portions of the North Park Street Code area, particularly those underlain thick deposits of younger Bay Mud, are susceptible to settlement. Younger Bay Mud is highly compressible and has low strength. The weight of the overlying materials (which include shallower Bay Mud, proposed new fill, and structures) causes consolidation of the sediments over time. As the sediments consolidate at depth, the ground surface settles and structural damage can occur. Subsidence related to consolidation of younger Bay Mud beneath fill and foundation settlement directly related to site-specific structural building loads could affect any structure in the North Park Street Code area. Underground utilities could also experience differential settlements along their alignments, possibly resulting in rupture or leakage, which could cause disruption of service or safety hazards.

The following mitigation measure should be implemented in order to reduce this impact to a less-than-significant level.

<u>**Mitigation Measure GEO-3:**</u> Proponents for all projects within the North Park Street Code area shall be required to prepare a geotechnical report for review and approval by the City of Alameda that specifies all measures necessary to limit consolidation including minimization of structural fills and use (when necessary) of lightweight and low plasticity fill materials to reduce the potential for excessive loading caused by fill placement. The report shall present recommendations for specific foundation designs, which minimize the potential for damage related to settlement. The design of utilities shall consider differential settlements along utility alignments constructed in filled areas of the North Park Street Code area.

Implementation of this mitigation measure would reduce the impact of continuing consolidation and land subsidence to less than significant levels.

Impact GEO-4: Damage to structures or property related to shrink-swell potential of North Park Street Code area soils could occur.

Bay Mud deposits, which could be encountered at shallow depths in portions of the entire North Park Street Code area, have moderate to high shrink/swell potential. This condition occurs when expansive soils undergo alternate cycles of wetting (swelling) and drying (shrinking). During these cycles, the volume of the soil changes significantly. Structural damage, warping, cracking of roads and sidewalks, and rupture of utility lines may occur if the potential expansive soils were not considered during design and construction of improvements. Building foundations placed on expansive soils can also be deformed by this process.

> **<u>Mitigation Measure GEO-4</u>:** The required geotechnical report shall require that subgrade soils for pavements consist of moisture-conditioned, lime-treated, or non-expansive soil, and that surface (including roof drainage) and subsurface water be directed away from foundation elements and into storm drains to minimize variations in soil moisture.

Implementation of this mitigation measure would reduce the impact of expansive soils to less than significant levels.